IOT BASED SMART CROP SUGGESTION SYSTEM

19-015

Project Proposal Report

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DECLARATION

We declare that this is our own work and this proposal does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other university or Institute of higher learning and to the best of our knowledge and belief does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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ABSTRACT

Among leading revenue industries in Sri Lanka, Agricultural industry plays a strategic role in the process of economic development of our country. One of the significant issues currently in the industry is deprive an accurate and easy way to realize the most suitable crop that can be grown in a particular land and soil degradation due to excess fertilizer usage. This research mainly focuses on suggesting the best crop that can be grown in a particular land with the existing nutrient levels in soil and a better fertilizer plan for better harvest on behalf of the money invested.

Nutrient levels in soil directly affect the growth of each crop and farmers have lack of knowledge about those nutrients. So in the current system most of the farmers cultivate crops by believing myths in society, and very few of them use scientific approaches. Believing myths is risky because crops related to myths may not always be the most suitable crop to grow in that particular ground. For scientific approach farmers need to test soil with the help of agricultural department. People need to travel long way to test soil by giving soil samples to agricultural department. It takes very large cost and as well as we can't consider it as the overall soil result of the land. So result may vary with point to point of the land.

This research mainly focuses both to build a tool with embedded sensors that measure the nutrient levels in soil which affects the growth of a plant and deploy a cross platform mobile application which facilitate farmers to identify the best crops that can be grown according to available nutrients in soil. Addition to that, a fertilizer plan will be suggested.

We test soil samples in a new land with our system by applying app suggested fertilizers in necessary amounts to that soil sample and compare the result with a soil samples in areas where a particular plant is well growing to evaluate our final product. We test soil samples in a new land with our system by applying app suggested fertilizers in necessary amounts to that soil sample and compare the result with a soil samples in areas where a particular plant is well growing to evaluate our final product.

TABLE OF CONTENTS

TABLE OF FIGURES

1. INTRODUCTION

1.1 Background

Now a day's people are so busy with their day-to-day works, they have a very limited time to fulfill all the responsibilities. So that they tend to use the things which helps to save their time to do their daily tasks. They have increasingly used to depend on machinery, rather than doing the things manually. Recently this technique got more popular in cultivation field too. Earlier days farmers had to use so much human power to fulfill their needs in cultivation. But now using a single machine alone with only one person to control it can gain the same amount of work with lesser time and lesser money.

Knowing the conditions which are required to grow the plant we desired to grow is the key point of a successful cultivation. For that we need to know very well about the soil type we are dealing with as well as the environmental conditions. Environmental conditions are not easy to change if we are assuming to start an outdoor plantation. But we can apply different nutrient types that helps to grow the plants well which leads to have a successful result. To identify the soil better in that specific ground, we can perform a soil test. Soil test is basically a series of tests which helps to identify the nutrient level of the soil.

Now a days, the most trusted soil testing mechanism is testing the soil with the help of professionals in the nearest laboratory. But majority of the people don’t have enough time to visit the laboratories or can be a beginner without much knowledge about cultivation. So they will believe the myths people say about the best crops for a particular area and grow it without thinking much.

Maybe trying plantations with believing myths will be a success, but we cannot guarantee that it is the best option that someone can decide on. The soil conditions will vary with the time. So it will be helpful if the owner can get notify time to time with a nutrient plan which helps to adjust the soil to gain more results from the ground.

According to a research by Department of Economic and Social Affairs in United Nation, New York, the current world population of 7.3 billion is expected to reach 8.5 billion by 2030 and 9.7 billion in 2050 [1]. So the amount of the people who need to feed will be increased day by day. Therefor we need to have a better cultivation system than the manual, traditional system.

If there is a way for people to identify the best plant according to the environmental conditions in the area and the soil type of their ground by their own, it will be a very helpful solution for the better results and to saves time.

The proposed system is basically based on using Internet of Things (IOT) and so that it leads to use technology on fulfilling cultivation purposes effectively and efficiently.

1.2. Literature Review

Design the sensor sub system using pH sensor, humidity sensors and build a co-relation between relevant fertilizers

As we utilizing pH sensors and moistness sensors, we have to get readings as parameters for fabricate the co-relationship which make the bury association between datasets. To get the readings and store them, we use raspberry pi board as our principle sensor center point.

Raspberry pi fill in as a little PC and compound with a microSD card, and a power supply and we can interface a reasonable showcase utilizing a HDMI link if need. What's more, can be utilized as a customary PC, utilizing USB console and mouse. And furthermore pi board has an incorporated WIFI module which can interface web. Along these lines, we can without much of a stretch transfer our datasets to a cloud server.

In horticulture, the pH is likely the most vital single property of the dampness related with a dirt, since that sign uncovers what yields will develop promptly in the dirt and what alterations must be made to adjust it for developing some other harvests.

Moistness is the sum of water vapor noticeable all around. To an extreme or too little humidity can be hazardous. For instance, high humidity joined with hot temperatures is a blend that can be a wellbeing hazard, particularly for the extremely youthful and the exceptionally old.

A relative dampness of 100% implies that the air can't hold any more water vapor. It's completely soaked. At the point when this happens, it can rain. Actually, the relative stickiness must be 100% where mists are framing for it to rain. Notwithstanding, at ground level where the downpour lands, the relative mugginess can be under 100%.

As per the farming bureau of sri lanka, NPK is the fundamental supplements which influence to develop the plants so that getting NPK rates in the dirt is progressively imperative.

Nitrogen (N) assurance in the research center as per John Kjeldahl (1883) technique: -

Test pre-treatment: It is essential that all examples to be pretreated to consent to the standard in the field of soil. Care was taken amid the processing so that not to misfortune measure of nitrogen, in this way, the temperature was under 400°C. The methodology: Right off the bat, the homogeneity of the research facility test just as the test was ensured.

- Digestion: Dried and crushed example segment of 0.2 gram (expected nitrogen content equivalent to 0.5%) to one gram (expected nitrogen content roughly 0.1%) was utilized. At the point when 10 ml sulfuric corrosive (4.2) was included, whirled until the corrosive was altogether blended with the example. The blend was permitted to represent cooling. At that point 2,5 g of the impetus blend 4.3 was included and warmed till the assimilation blend turned out to be clear. The blend was bubbled delicately for 5 hours to permit the sulfuric corrosive gathers around 1/3 as far as possible of the cylinder. The temperature of the arrangement was kept up underneath 400 °C[5]

- Titration: After processing was finished, the cylinder was left to cool; and 20 ml of water was included with gradually shaking. At that point the suspension was exchange to the refining device 5.4. At the point when; 5 ml of boric corrosive 4.5 was added to a 200 ml cone shaped jar and set under the condenser of the refining contraption so that the finish of the condenser dunks into the arrangement. At that point 20 ml of sodium hydroxide 4.4 was added to the pipe of the mechanical assembly and ran the antacid gradually into the refining chamber. From that point, around 100 ml of condensate was refined, wash the finish of the condenser, at that point few drops of blended marker 4.6 were added to the distillated and titrated with sulfuric corrosive 4.7 to a violet endpoint. Steam refining was utilized. Refining was ceased when 100 ml of refining was gathered.

- Calibration: Adjustment substances with known and unchangeable substance of nitrogen were utilized to control the processing and the mechanical assembly. Sulfanil corrosive with realized nitrogen content was utilized. Other than these substances ensured reference materials were utilized also to control the entire method

- Blank assurance: Two clear conclusions were done in every arrangement and the normal clear esteem was utilized for ensuing estimations.

- Duplicate assurance: From the submitted test for examination, two sub-tests were tried. Control limit for contrasts between the aftereffects of the tow sub test was built up, and exactness was resolved.

- Method of figuring: The substance of nitrogen, (wN), in milligrams per gram was determined utilizing the equation:

$$wN = (V1 - V0) \times c\ (H+) \times MN \times 100 /m \times mt\ [8]$$

- Where: V1 is the volume in millimeters of sulfuric corrosive (4.7) utilized in the titration of the example. V0 is the volume in milliliters, of the sulfuric corrosive (4.7) utilized in the titration of the clear test c (H+) is the centralization of H+ in the sulfuric corrosive (4.7) in moles per liter (for example in the event that 0.01 mol/l sulfuric corrosive is utilized, c(H+) = 0.02 mol/l). MN is the molar mass of nitrogen in grams per mole (=14) m is the mass of test mt is the dry buildup, communicated as g/100g based on stove dried assurance of Phosphorus in the research center[6]

To separate Phosphorus, all around shaked 1 g of air dried soil in 10 mL of 0.025 M HCl and 0.03 M NH4F for 5 minutes was readied. Phosphorus was resolved on the filtrate by the molybdate-blue strategy utilizing ascorbic corrosive as a hesitant. Shading improvement was estimated at 880 nm on a Brinkmann PC 800 test colorimeter.

Assurance of Replaceable Potassium:

Potassium was separated from the dirt by blending 10 milliliters of 1 ordinary, unbiased, ammonium acetic acid derivation with a 1-gram scoop of soil and shaken for 5 minutes. The interchangeable potassium was estimated by breaking down the sifted concentrate on a nuclear assimilation spectrophotometer set on discharge mode at 776 mm. The outcomes were accounted for as parts per million (ppm) of potassium (K) in the dirt. Soil test of 20 gm was well shaken with 40 ml of refined water in a 250 ml tapered jar for 60 minutes. At that point conductivity of the supernatant (immersion concentrate of soil) fluid was resolved with the assistance of conductivity meter.[8]

As appeared above we can get the NPK esteems from soil tests other than that pH and mugginess can get by utilizing significant sensor readings. Utilizing those readings, we assemble a connection between NPK with pH and moistness

We accept to get soil informational collections by utilizing criss cross technique to accomplish the best outcome and get soil informational indexes by 1 meter by 1 meter.

Fertilizer suggestion module for app suggested crop list and suggest suitability of user searched crop [12]

A group of researchers Komal Abhang, Surabhi Chaughule, Pranali Chavan, Shraddha Ganjave has done a research on soil analysis and crop fertility prediction after referring results gathered by testing the particular ground soil by normal lab tests done by the agricultural department.

The main aim of our System is to Atomize current manual soil testing procedure. In our system we are building handheld device using pH meter which will give pH value of soil. pH is negative log of hydronium ion mole per liter pH = - log [$H3O+$]. With help of this pH value we will estimate NPK of that soil, which are necessary Macronutrients of soil.

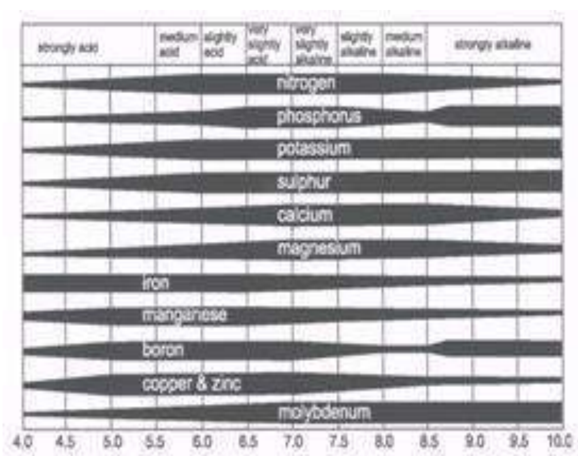


Figure 1: Nutrients present at particular pH value [12]

These will decide fertility of soil. For our software model we will be training crop database and we will classify that particular soil sample into particular class using classification algorithm. Depending on class determined by our system we will give list of crops suitable for that particular soil sample. Also provide suggestion of fertilizer for particular crop.

Nitrogen, phosphorus, and potassium are the main components of soil fertilizer. These methods isolate each nutrient from the soil into a solution that can be analyzed using turbidity and color to determine the concentration of nutrients present in the soil sample. Knowing present concentration informs environmental scientists of a nutrient deficiency or surplus in soils used to support plant production, and also provides general insight into basic biogeochemical cycles of an ecosystem.

Traditional soil testing presents a nearly insurmountable problem for farmers of small parcels. A second simplification tool for site-specific nutrient management for small farmers is the soil test kit. Access to soil test results such as those used to develop maps of soil properties are very difficult or impossible for farmers of small land parcels. Soil testing laboratories often do not even exist in most developing countries of the tropics. The soil test kit is not intended to serve as a replacement for standard soil testing but designed to enable extension officers and farmers to diagnose nutrient extreme deficiencies and excesses. Even when standard laboratories are available, the delay between sample collection and when the results are received may often preclude use of the results in the fertilizer decision making. It is an unusual farmer manager who anticipates the fertilization decision and sends in a soil sample in preparation for the decision.

The soil test kit permits obtaining a measure of soil pH, nitrate and ammonium, phosphorus, and potassium within about 30 to 45 minutes and can short-circuit the lengthy delays typical of soil testing Many soil scientists disbelieve the results from soil test kits, sometimes with good reason. Seldom is there sufficient training or any training at all with commercially available test kits and seldom are users given the information about which steps of the determination are critical and which are not.[6] For example, identified through the Participatory Learning Forum, have been successfully taught to use soil test kits as part of the site-specific nutrient management process described herein

Granary	Location (Season)	FERTO Rate				Farmer Rate		
		N	P_2O_5	K_2O	CM (kg/ha)	N	P_2O_5	K_2O
MADA	Kobah (1/2000)	197	95	150	1568	135	75	55
KADA	Ketereh (1/2001)	137	49	129	3400	149	89	69
	Meranti (1/2002)	188	85	195	3400	192	110	124
	Meranti (2/2002)	124	94	221	2393	192	110	124
	Meranti (1/2003)	124	94	221	800	192	110	124
	Senor (1/2003)	149	95	222	2418	150	90	70

Figure 2 : FERTO package and farmer fertilizer rates used in the study locations [2]

Fertilizer recommendation rate[9]

Figure 2 shows the fertilizer recommendation rates that were generated by FERTO package for plots in MADA and KADA areas, based on the physico-chemical properties of the soils and the set yield target. The recommendations had fertilizer rates ranging between 124 and 197 kg/ha for N, 45 and 95 kg/ha for P_2O_5, 129 and 222 kg/ha for K_2O, and between 800 and 3400 kg/ha for chicken manure (CM). Generally, potassium fertilizer and chicken manure are recommended in higher amounts for crop in KADA, than in MADA. It is due to low potassium and cation exchange capacity (CEC) status of KADA soils, thus inability to enhance high yield. Soils originating from riverine alluvium with 1:1 parent material clay like KADA are generally of low inherent fertility status. MADA soil with marine 2:1 clay are always better in fertility status as indicated by their high organic matter content and CEC status. These two parameters are important to ensure that the fertilizer applied can be held by the soil before it can be taken up by the crop. Otherwise, the crop has less opportunity to absorb the applied fertilizer because most of it will be lost through leaching process.

Normally, applied fertilizer is recommended to be split into various applications timing to optimize crop nutrient uptake and minimize loss through leaching and evaporation processes. Therefore, FERTO package recommends four split applications, i.e. basal dressing, first top-dressing, second top-dressing, and final top-dressing during specific crop growing stages (Table 3). For basal application, compound fertilizer (15:15:15) at a blanket rate of 200 kg/ha was applied at seedling stage, about 15 days after seeding (DAS). Split applications of straight fertilizers for top-dressing were varied according to locality, depending on the rates recommended by FERTO package (Abd Razak *et al.*, 2004). Chicken manure, if recommended, will be applied at early tillering stage, about 25 DAS. Fertilizer rate for each split application will be calculated by the model as formulated in the knowledge base. High N and K_2O rates were recommended at vegetative and reproductive stages, respectively. This will ensure development of quality tillers and productive panicles to attain high yield performance. [10]

Generating the fertilizer plan for the selected crop [5]

The researchers Joon-Goo Lee and Haedong Lee, Aekyung Moon in Electronics and Telecommunications Research Institute, Daegu, Korea has done a research on monitoring and the prediction of crop growth by using image processing technique.

They have gathered the required information such as location, size, leap area index, canopy of the crop and suggested the effective segmentation method of Crop of Interest (COI) at horticulture greenhouse. They have proposed to do their research in two ways. Such as,

- A colour image of the crop is segmented the green and non-green region.
- A depth image of the crop is removed near crops as rear crops and both sided crops

They have tried to overcome the problems in the existing methods which use threshold of each colour channel. So to overcome those errors they have suggested to use a ratio of each colour channel that is strong on changeable illuminance. [2]

Researchers, B. MiloviC and V. RadojeviC has done a research on the importance of data mining in Agriculture. In order to maintain the growth of the selected crop and generate a fertilizer plan we need to handle widely distributed data set with the nutrient levels the plant need in different time periods. So data mining technique will be useful to organize the data set and gather the required data by using patterns and algorithms.
There are many types of data mining techniques we can use for agriculture according to their research. [3]

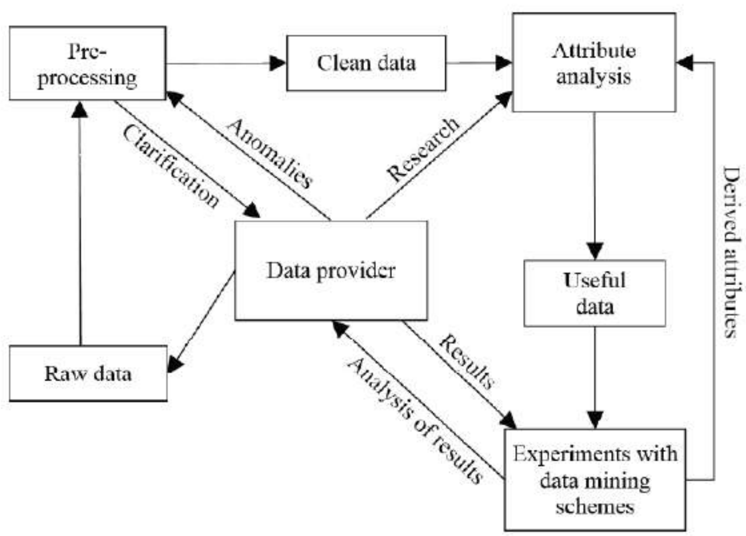


Figure 3: Process model for a machine learning [3]

K-mean in Agriculture:

The K-means algorithm is distance based clustering techniques. By applying this algorithm, K cluster are formed. Based on Euclidean distance, object is placed into the respective cluster. The k-means algorithm is used to classify soil in combination with GPS.

Classification of plant and soil, grading apples before marketing, Monitoring water quality change, detecting weeds in precision agriculture, and the prediction of wine fermentation problems can be performed by using a k-means approach.

K-nearest neighbor in Agriculture:

In pattern recognition, the k-Nearest Neighbors algorithm is a non-parametric method used for classification and regression. In Agriculture, k-NN algorithm is used in simulating daily precipitations and other weather variables and Estimating soil water parameters and Climate forecasting.

Neural Networks in Agriculture:

In data mining a statistical model known as Artificial Neural Network is a Non-linear predictive model that learns through training and resembles biological neural networks in structure.

The neural network is used in Prediction of flowering and maturity dates of soybean and in forecasting of water resources variables in agriculture.

SVMs in Agriculture:

Support vector machine (SVM) which was originally developed by Vapnik (1998) has been widely applied to many different fields, such as signal process and time series analysis.
SVMs are one of the newest supervised machine learning techniques.
The current study investigated the applicability of support vector machine in agriculture is in the crop classification and in the analysis of the climate change scenarios.

Decision Tree in Agriculture:

Decision Tree is tree-shaped structures that represent sets of decisions and generate rules for the classification of a dataset. Specific decision tree methods include Classification and Regression Trees (CART) and Chi Square Automatic Interaction Detection (CHAID).
In agriculture, Decision tree algorithm is used for predicting soil fertility.

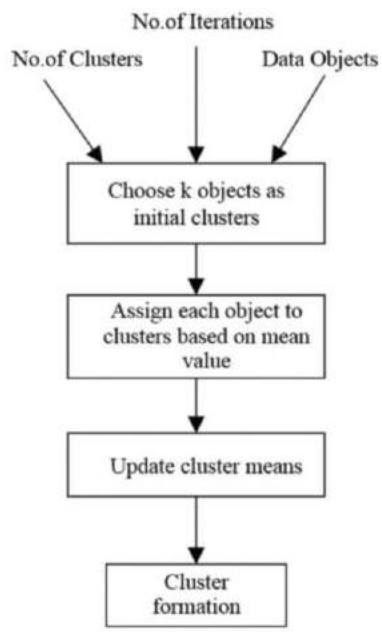


Figure 4: Cluster formation using k-means [3]

1.3. Research Gap

Based on the literature survey, we have realized that there are significant amount of research projects has been carried out according to the proposed solution we have discussed in this proposal below.

Almost all of the projects were carried out by doing laboratory tests with using various chemicals or using expensive sensors to check the nutrient levels in the soil. But to do a laboratory tests, people has to carry out the soil samples to the agricultural departments and it needs much time and cost. So we have decided to develop a tool with attaching sensors which will test the main factors like electrical conductivity (EC) and humidity of the soil.

According to the literature review, we have realised that using sensors to test the nutrient factors of the soil will lead to spend the user a lot of money. But we are planning to make this proposed solution which can be used by many users with spending less money. So we are planning to test the soil nutrient factors such as Nitrogen(N), Phosphorus(P), Potassium(K) as respect to the values of changing pH levels.

Some researchers have gathered the soil samples by taking it in different layers from the same place in the ground. But we are going to use the zig-zag soil testing method which needs to take soil samples from the different places in the ground in a zig-zag pattern. Using this method will be helpful to generate a most correct result about the soil nutrients as it tests the soil types through the whole ground.

1.4. Research Problem

When concluding the study of existing methods use by farmers to select the suitable crop for a particular land, we have realized that there is major problem that should take in to account which is not having an accurate and proper way to know the most suitable crop for a particular land/state. Since we are evolved with the technology, we finalized that it is better to have proper system that can be utilized in agriculture field efficiently in order to overcome this problem.

Analyzing soil before starting a cultivation is an important fact as soil nutrients are one of the major factors that affects growth of a plant. Some plant is sensitive to alkalinity and acidity of the soil and may not give a better harvest if failed to fulfill the needed conditions. Practically farmers have lack of knowledge about soil nutrient levels and also there is not an easy way to analyze soil nutrient levels in a land. Because of that in the existing system, most of the farmers start their cultivations by believing myths in society. Believing myths is risky because crops related to myths may not always be the most suitable crop to grow in that particular land. As well as believing myths is useless if the land is filled with new soil. So farmers fail to achieve better harvest with the existing soil nutrients.

In addition to that, very few of farmers use scientific approaches to identify the most suitable crop for the land. For that farmers need to test soil samples with the help of agriculture department. People need to travel long way to test soil in their land by giving soil samples to agriculture department and it is not an efficient way as lab test may take days to give results. Also it takes very large cost and as well as we can’t consider it as the overall soil result of the land as nutrient levels in a land varies from point to point. It may cause wasting of both time and money of the farmer.

Other major problem is soil degradation occurs due to not identifying the best crop that can be cultivated in a particular land with minimum fertilizer usage. When farmers fail to identify the suitable crop for existing soil nutrient levels in land, they have to use more fertilizer which affects soil health badly.

New cultivators who are new to agriculture industry are facing many problems as they do not have a broad knowledge about cultivations. If they failed at the beginning, they won't engage in agriculture industry further. So it better for both farmers and inexperienced beginners to have a more accurate and efficient solution to identify best crop that can be grown in a particular ground and a parallel fertilizer plan according to the existing soil nutrients, as it avoids wastage of their both time and money.

2. OBJECTIVES

2.1. Main Objectives

The main expectation of this project is to develop a fully functionally mobile app which capable to suggest the suitability of land to seed crops. This app is mainly focus on agricultural peoples who wish to seed new crops in a new soil land which hasn't seed particular seed before. By using the app people will be encouraging to seed smarter using recommended fertilizer levels with most suitable crop to the particular land.

2.2. Specific Objectives

- ✓ To estimate fertility status of soil and can easily identify the best crop that can plant in that land
    - Using the sensor readings and compare them with relevant data sets people can identify the best option for plant, we gather data sets to maintain best environment and fertility levels for main commercial crops such as paddy, rubber, coconut and tea.
- ✓ To change nutrient level in soil according to crop we need to grow. So, can gain good result
    - Using this method, we can reduce the failure of plantations according to law and unbalance fertility level. Most common method in current using is believe in myths. But with the relevant information farmers have more confidence to plant and they can check and maintain plantation with major stages of the crop in case of low growing.
- ✓ To use by any person to start their own plantation

- With the help of this method famers can start plantation without having any basic knowledge about the crops they going to plant. So that most of time and cost is reducing with the help of this method. As an example, farmer only want a minimum knowledge about operate the tool. It will suggest everything which necessary to plant the relevant crop. In the beginning of plantation every farmer may have doubts about the fertilizer levels. In present, farmers have to go for agriculture department with soil samples and do lab test which take couple of days. But with the help of this method

✓ To provide a basis for fertilizer recommendation for a given crop

- In plantation there are several stages which passing by the plant. so that requirements of fertilizers for plants can be vary. As an example, phosphorus percentage is more needed for plants when they come to their blooming stage. Farmers will get know what's the exact fertilizers should give more in particular stages.

✓ To Reduce the risk of not being able to have good result from plantations

- By maintaining recommended fertilizer levels plants will go through their growth stages with rich required fertilizer percentages. Therefore, it will reduce the risk of failure in plantations.

✓ To make people encouraged to start plantation more

- Most of people are not start plantation because of the doubts about plant growth and if any case they have to go for advises to agriculture departments. Using this tool, no need to wait for lab test results of soil testing's, can easily identify the relevant fertilizer levels and the people are encouraged to plant more. Its easy to use and easy to handle and quick responsible.

- ✓ Save the soil
    - Most of people don’t have an idea about how much we apply fertilizers on land. Therefore, they might apply over the limit and soil can be damaged by it. Using the app will show the exact amount we should apply and it will be the recommended amount of fertilizer for both plant and soil.

3. METHODOLOGY

Predict the Suitable crop from the sensors and chemical generated information.[10]

Soil testing is an important diagnostic tool for determining the nutrient needs of plants and for environmental assessments. Some soils are inherently deficient in plant nutrients. Other soils had sufficient levels of nutrients in the past, but removal with crop harvest has depleted the reserves. Thus, soil testing is widely accepted and used in most advanced crop-production areas of the world to determine fertilization needs for crops. Soil testing can also be used to identify application rates of waste materials containing nutrients or other elements that could harm the environment. Waste materials such as animal manures and industry by-products may provide various plant nutrients. However, high application rates to soils designed to dispose of the material at a low cost may result in nutrient loads that are harmful to plant, animal, or human health. Nutrient management regulations are being developed to address land application of waste materials. Soil testing is required in many regulations and management guidelines to assess environmentally harmful levels of certain elements and to determine limits to application rates.

Soils are tried routinely for the essential supplements phosphorus (P), potassium (K), and nitrogen (N). In certain locales, soils are additionally routinely tried for other essential supplements, for example, calcium (Ca), magnesium (Mg), and sulfur (S), and for different supplements required in exceptionally little sums by yields, for example, boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn). Soils accepting waste materials are additionally tried for components, for example, arsenic (As), cadmium (Cd), nickel (Ni), lead (Pb), mercury (Hg), and selenium (Se) among others.

The initial phase in deciding plant supplement necessities is settling on what sort of yield or plants will be developed and the turn of harvests or plants for the time of the supplement the board plan. After this choice has been made, an assurance of the required supplements is required. The essential method for making this assurance by and large is by soil testing.

Soil testing is the best strategy accessible for deciding how much supplement is required for ideal generation of generally crops. For certain yields, the utilization of plant examination might be the favored technique for deciding harvest supplement needs. Settling on supplement application choices without soil testing or plant examination can be a dangerous undertaking since this will most likely outcome in decreased benefit from either under-or over applying supplements; moreover, over application of supplements can result in diminished water quality. It is vital to pursue suggested methodology for taking soil and plant tests.

When making N suggestions for some harvests, the deciding variable on the amount N to apply depends on the normal yield of the yield. The best strategy for deciding expected yield is from past yield records. It is vital to utilize a normal yield that is practical, in such a case that a normal yield is utilized that is a lot more prominent than can be accomplished reasonably then more supplement will be connected than the harvest can use. Applying abundance supplement builds the danger of supplements getting into close-by water supplies and imperiling water quality. In the meantime, utilizing a normal yield that is too low can restrict yields because of supplement lacks, which lessens gainfulness of harvest creation.

Some specific recommendations for soil analysis are summarized here:

1.Soil samples must be representative of the land area in question. The recommendation is to take a minimum of one composite sample per 12–15 ha for lime and fertilizer evaluations. A representative soil sample is composed of 15–20 subsamples from a uniform field with no major variation in slope, drainage, or past fertilizer history. Any of these listed factors, if changed, will have an effect on the number of samples and unit area from which the sample is obtained;

2.Depth of sampling for mobile nutrients such as N should be 60 cm and, for immobile nutrients such as P, K, Ca, and Mg, 15–20 cm. For pasture crops, a sampling depth of 10 cm is normally sufficient to evaluate nutrient status and make liming and fertilizer recommendations;

3. The app extractor must be selected. Three extracting solutions, 0.05 mol l^{-1} HCl +0.025 mol l^{-1} H_2SO_4 (Mehlich1),
0.03 mol l^{-1} NH_4F + 0.025 mol l^{-1} HCl (Bray-P1), and 0.5 mol l^{-1} $NaHCO_3$ at pH 8.5 (Olsen) are the most commonly used extractants for P at the present time and are generally adequate to cover a broad range of soils. Commonly used extractants for K, Ca, and Mg are double acid (Mehlich 1), 1 mol l^{-1} NH_4Ac at pH 7, and NaOAc at pH 4.8. Multielement extracting reagents are replacing the more familiar, single-element extractants. After mixing with an appropriate aliquot of soil, the obtained extract is assayed by an inductively coupled plasma emission spectrometer (ICP-AES). A flow-injection analyzer (FIA) is another multielement analyzer capable of assaying these soil extracts;

4. Optimum soil test values for macro- and micronutrients, which vary from soil to soil, crop to crop, and extraction to extraction, are required. They are usually approximately greater than 10 mg P kg^{-1}, greater than 50 mg K kg^{-1}, greater than 600 mg Ca kg^{-1}, greater than 120 mg Mg kg^{-1}, and greater than 12 mg S kg^{-1} for producing satisfactory results for most soils and crops. For micronutrients, the critical values reported are: Fe, 2.5–5 mg kg^{-1}; Mn, 4–8 mg kg^{-1}; Zn, 0.8–3 mg kg^{-1}; B, 0.1–2 mg kg^{-1}, Cu, 0.5–2 mg kg^{-1}, and Mo, 0.2–0.5 mg kg^{-1}, respectively;

5. pH values should be ascertained; the pH of agricultural soils is in the range of 4–9. It is difficult to define optimum pH values of different plant species. Most food crops grow well in acid soils of pH approximately 6. Lime is called the foundation of crop production or ‘workhorse’ in acid soils;

Electrical Conductivity (EC) [11]

The preferred index to assess soil salinity is electrical conductivity. Electrical conductivity measurements are reliable, inexpensive to do, and quick. Thus, EC is routinely measured in many soil testing laboratories. The EC is based on the concept that the electrical current carried by a salt solution under standard conditions increases as the salt concentration of the solution increases. A sample solution is placed between two electrodes of known geometry; an electrical potential is applied across the electrodes, and the resistance (R) of the solution between the electrodes is measured in ohms. The resistance of a conducting material (e.g., a salt solution) is inversely proportional to the cross-sectional area (A) and directly proportional to the length (L) of the conductivity cell that holds the sample and the electrodes. Specific resistance (R_s) is the resistance of a cube of a sample volume 1 cm on edge. Since most commercial conductivity cells are not this large, only a portion of R_s is measured. This fraction is the cell constant ($K = R/R_s$). The reciprocal of resistance is conductance (C). It is expressed in reciprocal ohms or mhos. When the cell constant is included, the conductance is converted, at the temperature of the measurement, to specific conductance or the reciprocal of the specific resistance (Rhoades, 1993). The specific conductance is the EC (Rhoades, 1993), expressed as

(10.2)EC=1/Rs=K/R

Electrical conductivity is expressed in micromhos per centimeter µmho cm^{-1}) or in millimhos per centimeter (mmho cm^{-1}). In SI units the reciprocal of the ohm is the siemen

(S) and EC is given as S m^{-1}or as decisiemens per meter (dS m^{-1}). One dS m^{-1} is one mmho cm^{-1}. The EC at 298 K can be measured using the equation

(10.3)EC298=ECtfv

Where f_t is a temperature coefficient that can be determined from the relation f_t = 1 + 0.019 (*t*-298 K) and *t* is the temperature at which the experimental measurement is made in degrees Kelvin (Richards, 1954).

A number of EC values can be expressed according to the method employed: EC_e, the EC of the extract of a saturated paste of a soil sample; EC_p, the EC of the soil paste itself; EC_w, the EC of a soil solution or water sample; and EC_a, the EC of the bulk field soil (Rhoades, 1990).

The electrical conductivity of the extract of a saturated paste of a soil sample (EC_e) is a very common way to measure soil salinity. In this method, a saturated soil paste is prepared by adding distilled water to a 200- to 400-g sample of air-dry soil and stirring. The mixture should then stand for several hours so that the water and soil react and the readily soluble salts dissolve. This is necessary so that a uniformly saturated and equilibrated soil paste results. The soil paste should shine as it reflects light, flow some when the beaker is tipped, slide easily off a spatula, and easily consolidate when the container is tapped after a trench is formed in the paste with the spatula. The extract of the saturation paste can be obtained by suction using a Büchner funnel and filter paper. The EC and temperature of the extract are measured using conductance meters/cells and thermometers and EC_{298} is calculated using Eq. (10.3).

The EC_w values for many waters used in irrigation in the western United States are in the range 0.15-1.50 dS m^{-1}. Soil solutions and drainage waters normally have higher EC_w values (Richards, 1954). The EC_w of irrigation water < 0.7 dS m^{-1} is not a problem, but an EC_w> 3 dS m^{-1} can affect the growth of many crops (Ayers and Westcot, 1976).

It is often desirable to estimate EC based on soil solution data. Marion and Babcock (1976) developed a relationship between EC_w(dS m^{-1}) to total soluble salt concentration (TSS in mmol liter^{-1}) and ionic concentration (*C* in mmol liter^{-1}), where *C* is corrected for ion pairs. If there is no ion complexation, TSS = *C* (Jurinak and Suarez, 1990). The equations of Marion and Babcock (1976) are

(10.4)logundefinedC=0.955+1.039undefinedlogundefinedECw

(10.5)logundefinedTSS=0.990+1.055undefinedlogundefinedECw.

These work well to 15 dS m^{-1}, which covers the range of EC_e and $EC_w$for slightly to moderately saline soils (Bresler *et al*.,1982).

Griffin and Jurinak (1973) also developed an empirical relationship between EC_w and ionic strength (*I*) at 298 K that corrects for ion pairs and complexes

(10.6)I=0.0127undefinedECW

where EC_w is in dS m^{-1} at 298 K. Figure 10.2 shows the straight line relationship between *I* and EC_w predicted by Eq. (10.6), as compared to actual values for river waters and soil extracts.

There are few sensors that essential for this research. There are pH, humidity, temperature, EC.

Temperature Sensor

Figure 5: Temperature sensor [Source: Google]

Soil temperature sensors arrive in an assortment of structures utilizing thermistors, thermocouples, thermocouple wires, and averaging thermocouples. The electrical signs transmitted from the sensors to information lumberjacks can be changed over to various units of estimation, including °C , °F, and °K. Information lumberjacks are likewise equipped for estimating most financially accessible soil temperature sensors.

EC sensor

, Soil temperature sensors arrive in an assortment of structures utilizing thermistors, thermocouples, thermocouple wires, and averaging thermocouples. The electrical signs transmitted from the sensors to information lumberjacks can be changed over to various units of estimation, including °C , °F, and °K. Information lumberjacks are likewise equipped for estimating most financially accessible soil temperature sensors.**EC sensor**

EC sensor

Figure 6: EC sensor [Source: Google]

The WET Sensor has crucial applications in precision horticulture and soil science research and is usable in both soils and growing substrates. It is exceptional in its ability to measure pore water conductivity (ECp), the EC of the water that is available to the plant.

Crop suggestion [10]

As the proposed system is mainly focuses on to suggest the most suitable crop that can be grown in a particular ground, aim of developing this crop suggestion module using a relevant machine learning algorithm will fulfil that task.

Authors decided to deploy a cross platform mobile application and it facilitate farmers to select best crop and maintain the growth of the cultivation with a better fertilizer plan. At the beginning farmer has to enter both soil type and area of the ground in meters. App will automatically suggest the minimum reading count needed to take from the ground in order to generate the most accurate crop suggestion list.

Using the proposed tool farmer has to take reading from the ground and when the required reading count is fulfilled, App will retrieve sensor reading from the cloud server and will display average of sensor readings to farmer. Then app will analyze both ground type and average readings with in-built dataset in database and will suggest list of most suitable crops

If by any chance farmer wanted to grow different crop other than crops included in suggested list, he can search for that crop details. If the requested crop is somewhat suitable to grow, app will notify it to farmer with a suitable fertilizer plan. So the farmer can make the ground suitable for that crop to have a better harvest. In addition to that app will suggest suitable fertilizer plan for suggested best crop list to have the best harvest on behalf of the money invested.

As using pH sensors and humidity sensors, need to get readings as parameters for build the co-relationship which make the inter connection between datasets.to get the readings and store them use raspberry pi board as our main sensor hub.

Figure 7: pH sensor [Source: Google]

pH sensor

Figure 8: Humidity sensor [Source: Google]

Humidity sensor- DHT11 is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The calibration coefficients are stored as programs in the OTP memory, which are used by the sensor's internal signal detecting process. The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up-to-20-meter signal transmission making it the best choice for various applications, including those most demanding ones. The component is 4-pin single row pin package.

Raspberry pi work as a small computer and compound with a microSD card, and a power supply and we can connect a suitable display using a HDMI cable if need.

Raspberry pi

Figure 9: Raspberry pi [Source: Google]

And can be used as a traditional computer, using USB keyboard and mouse. and also pi board has an integrated WIFI module which can connect internet. Therefore, we can easily upload our datasets to a cloud server.

According to the agricultural department of sri lanka NPK is the main nutrients which affect to grow the plants so that getting NPK percentages in the soil is more important. So that need to clearly identify the NPK level by using the gathering readings.

To build up the co relationship between sensor reading and NPK levels need to do lab tests partially with Nitrogen (Nitrate NO_{3^-}), Phosphorus and Potassium. Getting these fertilizer extractions is followed as below.

1. Extraction of Nitrogen (Nitrate NO_{3^-})
   - 1.1. Turn on the balance, set a weigh boat on top, and zero the balance.
   - 1.2. Use a spatula to weigh out 10 g of soil (dried and sieved) and transfer to a labeled 100-mL beaker.

1.3. Weigh out 0.1 g of calcium sulfate and transfer it to the beaker.
1.4. Using a 25-mL graduated cylinder measure 20 mL of deionized water and transfer to the beaker.
1.5. Repeat steps 1.1 - 1.4 for each nitrogen soil sample.
1.6. Thoroughly mix the contents of each beaker with a stir rod.
1.7. Secure samples on a table-top shaker and shake for 1 min.

2. Extraction of Phosphorus and Potassium
   2.1. Turn on the balance, set a weigh boat on the top, and zero the balance.
   2.2. Use a spatula to weigh out 2 g of soil (dried and sieved) and transfer into a labeled 100-mL beaker.
   2.3. Use a 25-mL graduated cylinder to measure 20 mL of Mehlich 2 soil extractant into the cylinder. Transfer to beaker.
   2.4. Repeat steps 2.1 - 2.3 for each phosphorus and potassium sample.
   2.5. Thoroughly mix the contents of each beaker with a stir rod.
   2.6. Secure samples on a table-top shaker table and shake for 5 min.

3. Nutrient Extraction Filtration - This step will be performed for all three analytes (nitrate, phosphate, and potassium)
   3.1. Secure one end of the funnel hose onto a vacuum jet.
   3.2. Secure the other end of the hose to the side arm of the flask.
   3.3. Assemble the funnel by snapping together the cylinder and perforated top disk. Place the assembled funnel on top of the side-arm flask by inserting the rubber stopper into the top of the flask to secure the funnel on top.
   3.4. Place 1 clean filter paper on top of the funnel.
   3.5. Turn on the vacuum jet.
   3.6. Slowly pour soil extract solution into the funnel, allowing the extract to drain away from the soil and into the bottom of the funnel flask.

3.7. Pour filtered extract into a new, labeled 50-mL beaker. This filtrate will be analyzed as is.

3.8. Remove funnel, discard filter paper, and rinse funnel and flask with deionized water. Use air jet to dry funnel and flask.

3.9. Repeat steps 3.3 - 3.7 for each soil sample.

4. Sample Analysis with Color Comparator for Nitrate

4.1. Label one color viewing tube “S” for sample and another color viewing tube “B” for blank.

4.2. Thoroughly rinse both color viewing tubes with deionized water. Shake the tubes to remove the remaining rinse water.

4.3. Add a small amount of the sample extract (prepared in steps 1.1 - 1.7) about ¼" deep to the color viewing Tube marked “S”. Cap the tube with a rubber stopper and shake it for 3 s. Discard this solution.

4.4. Add the sample extract to both tubes until the meniscus is even with the 5-mL mark on the tubes (bottom of the frosted area).

4.5. Add the contents of one NitraVer 5 Powder Pillow to the tube marked “S”. Cap and shake the tube vigorously for exactly one minute.

4.6. Immediately place tubes “S” and “B” into the comparator with tube “B” in the outside hole and tube “S” in the inside hole.

4.7. Wait 5 min, then hold the color comparator up to a light source. Rotate the disc until the color in the window for tube “B” matches the color in the window for tube “S”. Record the concentration value (mg/L) that displays in the lower window of the color comparator box.

4.8. Repeat steps 4.1 - 4.7 for all replicates and record the average.

4.9. Repeat step 4.8 for all nitrate samples.

5. Sample Analysis with Color Comparator for Phosphate

5.1. Using the 2.5-mL dropper, add 2.5 mL of the filtered sample extract (prepared in steps 2.1 - 2.6) to a 25-mL graduated cylinder.

5.2. Dilute to the 25-mL mark with deionized water, cap with stopper, and invert to mix.

5.3. Label one color viewing tube “S” for sample and another color viewing Tube “B” for blank.

5.4. Thoroughly rinse both color viewing tubes with deionized water. Shake the tubes to remove the remaining rinse water.

5.5. Add a small amount of the diluted extract about ¼" deep to the color viewing tube marked “S”. Cap the tube with a rubber stopper and shake it for a few seconds then discard this solution.

5.6. Add the sample extract to both tubes until the meniscus is even with the 5-mL mark on the tubes (bottom of the frosted area).

5.7. Add the contents of one PhosVer 3 Powder Pillow to the “S” tube. Cap and shake the tube vigorously for one minute.

5.8. Immediately place tubes “S” and “B” into the comparator with tube “B” in the outside hole and tube “S” in the inside hole.

5.9. 3 min after completing Step 5.8, hold the color comparator up to a light source. Rotate the disc until the color in the window for tube “B” matches the color in the window for tube “S”. In a lower display area on the box, the color disk will simultaneously display the concentration value corresponding with the color intensity chosen. Record the concentration value that displays in the window.

5.10. Repeat steps 5.1 - 5.10 for all replicates and record the average.

5.11. Repeat step 5.10 for all phosphorus samples.

6. Reagent Addition and Analysis for Potassium

6.1. Using a 1-mL dropper, add 3 mL of potassium sample extract (prepared in steps 2.1 - 2.6) to a 25-mL cylinder.

6.2. Add DI water to the 21-mL mark on the cylinder. Firmly cap the cylinder with a rubber stopper and invert to mix.

6.3. Add one potassium 2 reagent powder pillow to the cylinder.

6.4. Add 3 mL of Alkaline EDTA solution to the cylinder.

6.5. Cap the cylinder and invert several times to mix. Allow solution to stand for 3 min.

6.6. Add the contents of one potassium 3 reagent powder pillow.

6.7. Firmly cap the cylinder and shake vigorously for 10 s.

6.8. Allow the solution to stand for 3 min as a white turbidity develops.

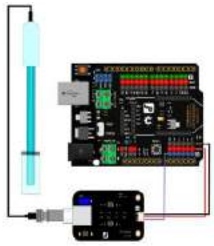
6.9. While looking straight down into the cylinder, slowly insert the potassium dipstick vertically into the solution until black dot is no longer visible from above the cylinder.

6.10. Hold dipstick in that position and rotate the cylinder so it can be seen the scale on the dipstick. Look across the surface of the scale on the dipstick. Record the number on the dipstick scale where the surface of the sample meets the dipstick scale.

6.11. Repeat 6.1- 6.10 for all replicates and average. Repeat 6.11 for all potassium samples.

6.12. Refer to the potassium conversion table to determine the concentration of potassium in soil samples. Locate the dipstick reading on the left column and record the corresponding mg/L concentration on the right column.

As the beginning build the sensor subsystem which include all the sensors (pH, EC, Humidity, Temperature). This will give the sensor reading to Raspberry pi board for further developments.



Connecting pH sensor to Raspberry pi board

Figure 10: Connecting pH sensor to Raspberry pi board [Source: Google]

Connecting humidity sensor to Raspberry pi board.

Figure 11: Connecting humidity sensor to Raspberry pi board. [Source: Google]

After the connect sensors to raspberry board connect the display to do the configuration to get the readings from sensors. Raspberry pi is using python coding language.

Connect the raspberry board to internet is the next task .do the relevant configurations to connect the board to the internet. And then upload the gathered data set to the cloud using the relevant API.

Module to suggest suitability of a requested crop with a fertilizer plan [8]

As the proposed system is mainly focuses on to suggest the most suitable crop that can be grown in a particular land, aim of developing this crop suggestion module using a relevant machine learning algorithm will fulfill that requirement.

Authors decided to deploy a cross platform mobile application and it facilitate farmers to select best crop and maintain the growth of the cultivation with a better fertilizer plan. At the beginning farmer has to enter both soil type and area of the land in meters. Then app will automatically suggest the minimum reading count needed to take from the land in order to generate the most accurate crop suggestion list.

Using the proposed tool farmer has to take reading from the land and when the required reading count is fulfilled, App will retrieve sensor reading from the cloud server and will display average of sensor readings to farmer. Then app will analyze both soil type and average readings with in-built dataset in database and will suggest list of most suitable crops.

If by any chance farmer wanted to grow different crop other than crops included in suggested list, he can search for that crop details. If the requested crop can be grown in the land only by adjusting the existing nutrient levels in soil, app suggest the amount of fertilizer that should be used in order to plant that crop. So the farmer can make the land suitable for that crop to have a better harvest. In addition to that app will suggest suitable fertilizer plan for suggested best crop list to have the best harvest on behalf of the money invested.

Fertilizer suggestion

In this research we are basically planning on focusing the nutrient levels in soil from different areas in Sri Lanka. Because there are many varieties in the soil in our country, there is a huge variety of soil types in Sri Lanka.

Because we are trying to keep the track of a plant, we need to store all the data according to the specific crop from the day it was planted. So for that, we are storing all the plant data using a cloud server which we can access anytime in the future. We can check the specific nutrition details the plant needs for a successful cultivation with comparing the sensor readings we get from testing the current soil type in the cloud with the records in the database.

According to the selected crop, we are going to generate a fertilizer plan. It will vary with the soil nutrient levels of the relevant ground at that current time. Each and every crop requires different kinds of fertilizers in different times. The matching fertilizers we can use for the growth of a single crop has so many varieties. So for that we have to have a huge database with various nutrition factors which are suitable for the selected crop. To get the relevant nutrition factors, we are planned to use data mining technique [5]. It will analyses the large data set of nutrition levels of the selected crop and establish relationships to solve problems through data analysis.

Tools and Technologies

Xamarin is one of the most cost effective and time efficient cross-platform which uses .NET framework. So Xamarin, is suitable for developing mobile apps that work on multiple mobile platforms, like Android, iOS, Windows etc. It provides the advantages of native UI, access to specific-device features, and most importantly, native performance. [8]

Boto3 is an Amazon Web Services (AWS) SDK for Python. It provides an easy to use, object-oriented API, as well as low-level access to AWS services and enables to create, configure and manage AWS services such as EC2 and S3. [9]

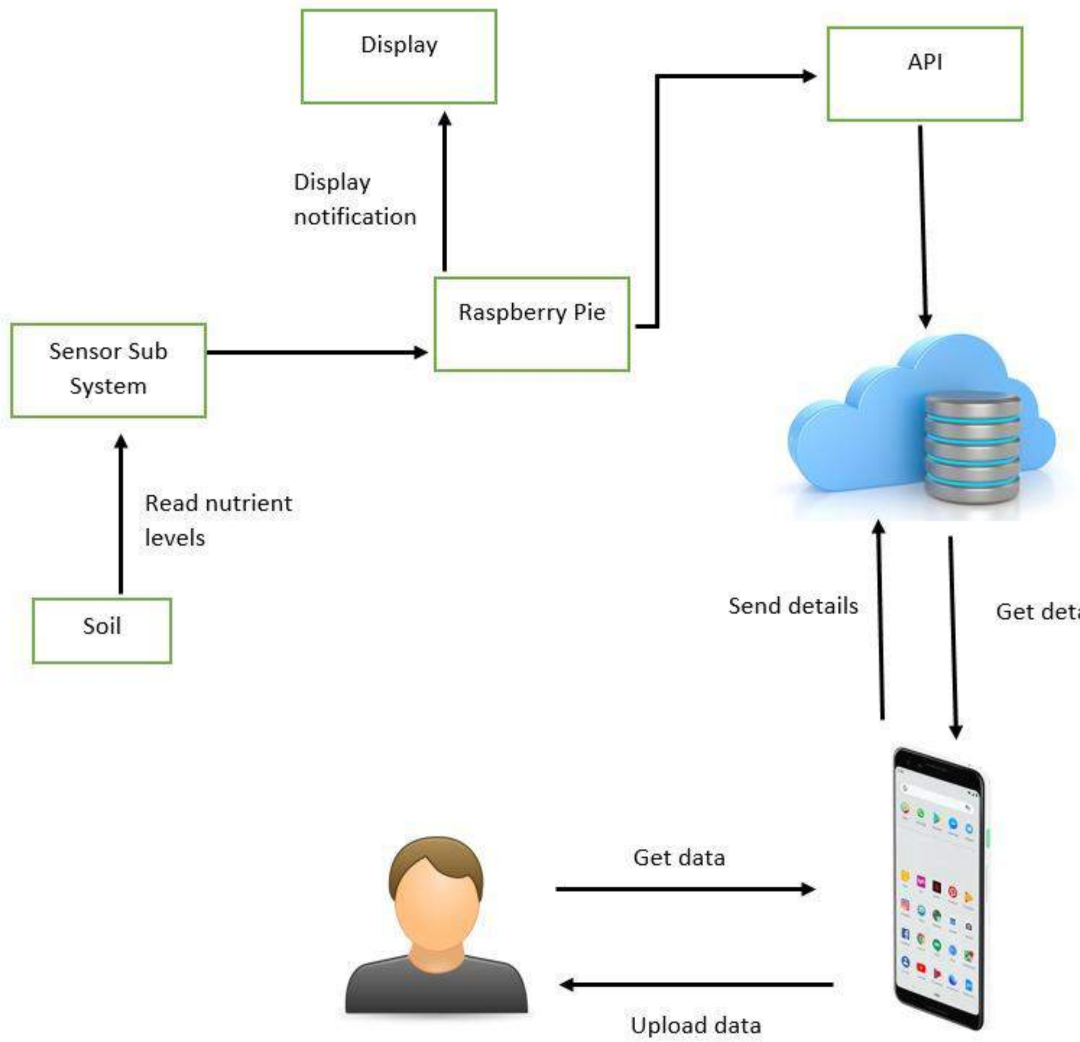
MySQL is free open source database and it is a stable ,reliable and the powerful solution with the advanced features.

It facilitate the effective management of the databases by connecting them to the software.It additionally has connectors

to languages like C#, C++, Java,Node.js,Python, and PHP, implying that it's not constrained to SQL query language.

MySQL is intended to meet even the most requesting applications while guaranteeing the ideal speed, full content record and the one of a kind memory reserves for the upgraded exhibitions.[10]

System Architecture



Name	Task	Description
C.P. Wickramasinghe	1.Develop a suitable sub system to get readings for the algorithm. 2. Configure the entire sensor sub system to establish the data communication. 3.Configure the system to communicate with cloud server. 4.Testing an implementation	1.1 Using Raspberry pi as the main evice use four sensors (pH, EC, Temperature, Moisture) to get the readings from soil to develop algorithms and for the comparison. 2.1 The signals come from sensors and captured by raspberry pi. 2.2 All data sends to a cloud. Android app retrieve data from cloud to predict suitable crop for the soil. 3.0 Connect the whole system with the internet and establish sensor data communication with cloud server. 4.0 Testing the accuracy of values, continuity of data transmission, accuracy of processing algorithm, and performance of the system.

H.P.H.S.Hemapriya	1.Analyze both ground type and average sensor readings with in-built data set in database and suggest most suitable crop using identified algorithm. 2.Recommend suitability of the crop searched by the farmer in addition to crop suggested by the app. 3.Developing a co-relationship to recommend necessary amount of fertilizer needed for have better harvest. 4 Database optimization 5 Developing android application to display the most suitable crop suggested by the algorithm.	1.1Select the ground type in the app and getting sensor readings and from both suggest most suitable crop compare with the data set in database. 2.0 recommend suitability of crop that farmer wants to grow on land. 3.0 Develop a co-relationship with retrieved sensor readings from cloud server and in-built data-set in database, to recommend necessary amount of fertilizer needed to have a better harvest from the app suggested crops 3.1 Addition to the app suggested crop list, farmer can search for a crop to grow according to his favor 4.0 Database optimization. 5.0 Developing the android application to generate and display the average sensor reading details and the most suitable crop suggested by the algorithm with using the minimum reading count suggestion mechanism in machine learning.

P.L.N. Lakshitha	1.Develop a sensor subsystem for get readings to build up the algorithm	1.1. Building up the algorithm of co relationships using relevant sensor readings such as pH, Ec, moisture, temperature. Use Raspberry pi as the main sensor hub to receive the readings from sensors and to analyze them.
	2.Establish the data communication between cloud and sensor readings.	2.1. As the main sensor hub, Raspberry pi capture the readings of data from sensors and upload them to the cloud server. 2.2. Cloud server keep the datasets and let them access by the android application to run the algorithms.
	3.Configure the communications to transfer data.	3.1. Configure the Raspberry pi connection to connect with internet.
	4.Testing and implementation	4.1. implement the system with relevant algorithms 4.2. Do unit testing and component testing for find and sort the issues and bugs

P.G.N.S.Ranasinghe	1.Configure a cloud server according to the system requirements. 2.Configure the entire sensor subsystem to establish the data communication with the cloud server. 3.Developing a co-relation to generate necessary amounts of fertilizers a farmer should apply to the cultivation to have a better harvest 4. Developing android application to display the most suitable crop suggested by the algorithm.	1.0 Select and configure a cloud server according to the system requirements for storing all the sensor readings and establish the data connection with the sensor subsystem. 2.0 establish the connection with raspberry pi and cloud server. 3.0 The stored details can be used to generate the future fertilizer plan for the best suitable crop by reminding the user about the times which they should to apply the fertilizer to maintain the growth of the plant in order to have a better harvest. 4.0 Developing the android application to generate and display the average sensor reading details and the most suitable crop suggested by the algorithm with using the minimum reading count suggestion mechanism in machine learning.

Budget

Description	Estimated Cost (Rs)
Raspberry pie 3 B+	13 000.00
Other components for Raspberry pie	1800.00
Sensors	5000.00
Miscellaneous	2000.00
Total	21800.00

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APENDICES

Gantt chart